Oct. 2, 1951 L. E. R. UMNEY 2,569,909

NONROTARY CENTRIFUGAL SEPARATOR

Filed Jan. 17, 1949 3 Sheets-Sheet 1

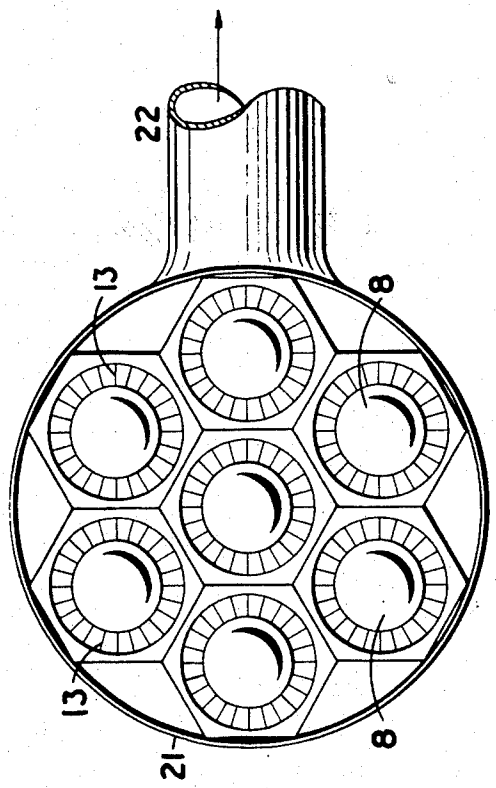

Fig. 2.

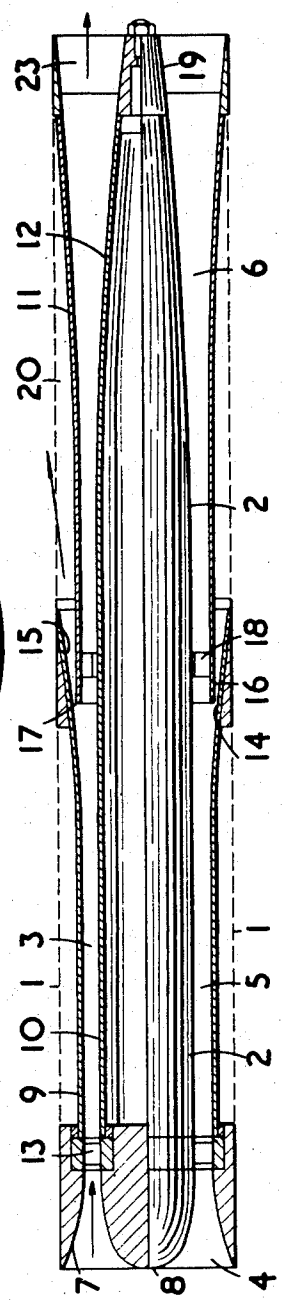

Fig. 1

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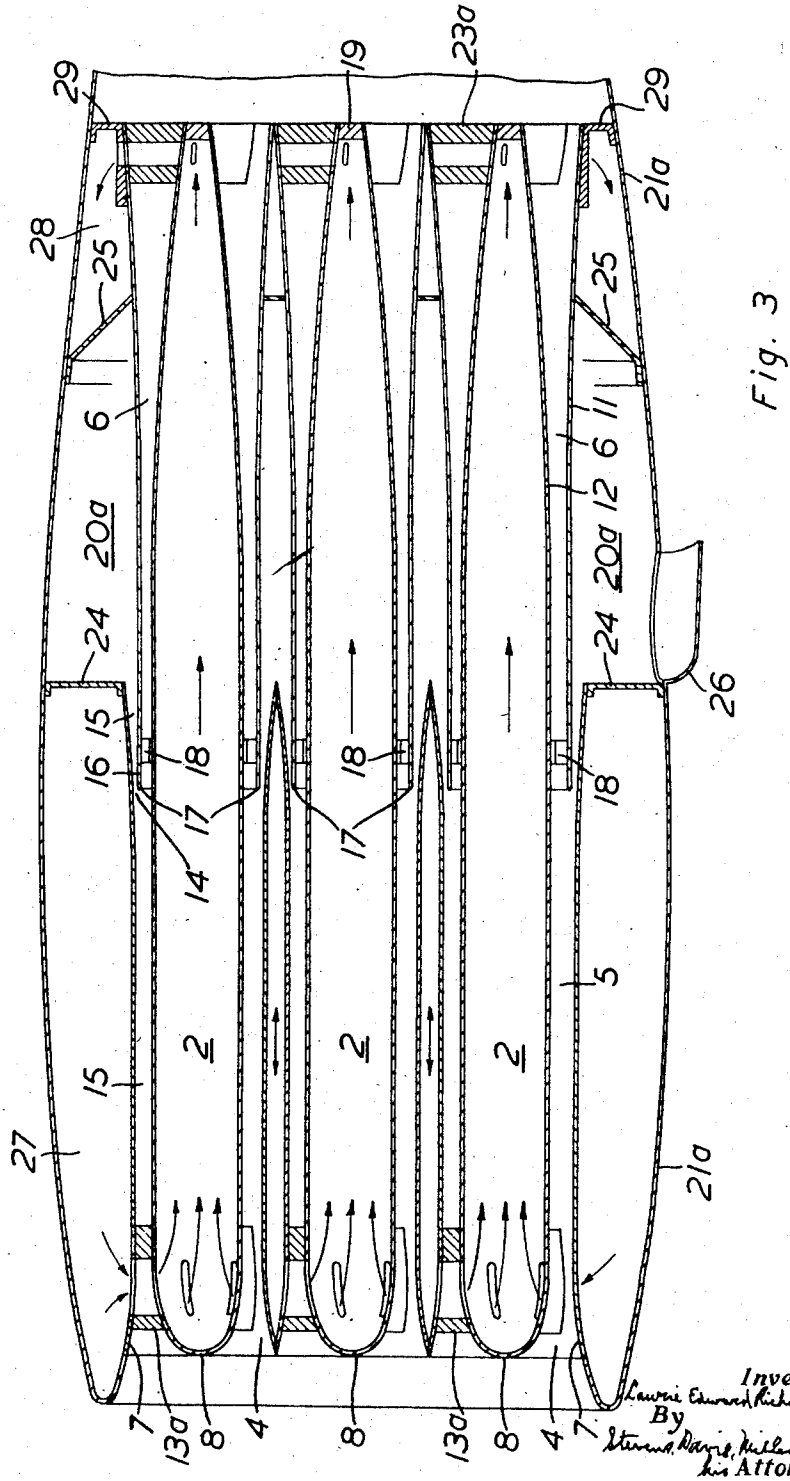

Fig. 3

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NONROTARY CENTRIFUGAL SEPARATOR

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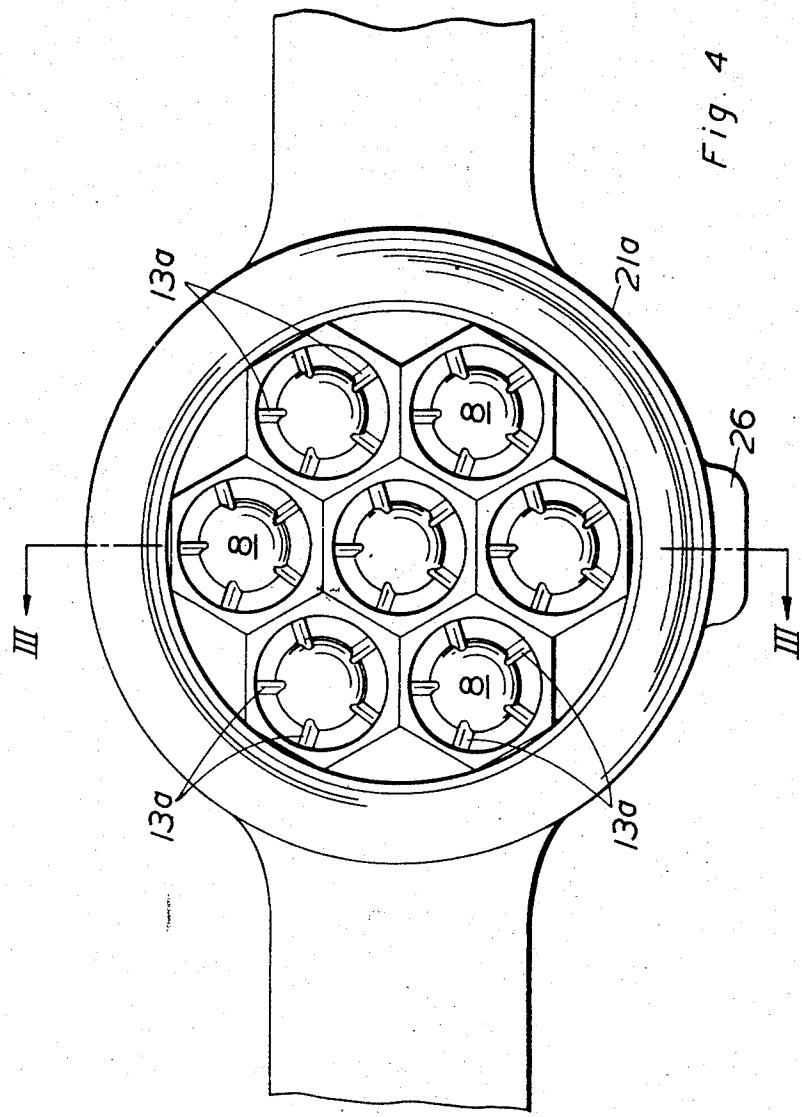

Fig. 4

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UNITED STATES PATENT OFFICE

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NONROTARY CENTRIFUGAL SEPARATOR

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Application January 17, 1949, Serial No. 71,382
In Great Britain January 26, 1948

4 Claims. (Cl. 183—80)

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This invention is for improvements in or relating to non-rotary centrifugal separators for operating on fluid media and in particular for separating foreign matter from air or gaseous media. "The term foreign matter is intended to include dust, dirt, and solid and liquid particles such as ice, snow and water particles."

A dust separator has been proposed in which the gaseous medium moves unidirectionally and in which the effect of centrifugal force is utilised to remove the heavier particles of dust and dirt from the medium by utilising a Venturi tube of which the passage is unobstructed, together with means for causing the dust-laden gas as it flows towards the throat of the Venturi tube, to whirl about the axis of the tube so that the dust and dirt is discharged by centrifugal action through an opening provided in the vicinity of the throat of the Venturi tube. With this device there is nothing to prevent break-away of the flow from itself to form a highly turbulent core in the inner region of the passage at the high swirls necessary for the separation of very small particles.

According to the present invention a non-rotary centrifugal separator for operating on fluid media employs a passage of annular form through which the fluid is passed with a swirling motion to produce a centrifuging effect, means being provided at an appropriate point in the length of the passage for removing fluid at the periphery of the whirl together with any foreign matter centrifuged into that region. By virtue of the annular form of the passage it is possible to maintain a higher whirl velocity without internal break-away of the flow from itself than otherwise would be possible.

If the supply of fluid does not already contain a suitable whirl (as it might in certain circumstances) then the apparatus would include blading or other suitable means for introducing such whirl. The whirl may be a form of forced vortex.

In order to avoid excessive overall length where large quantities of fluid are to be handled it is preferable to employ a plurality of relatively small diameter passages rather than one large passage and the invention contemplates therefore that the apparatus should be a self-contained unit capable of being combined with other similar units to form a battery, in which case each unit must produce its own whirl.

Thus, a practical form of unit may comprise in combination an open ended tubular member containing a streamlined core member, the two defining and forming between them a straight through annular passage for the passage of the fluid medium and the two shaped to form a

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smoothly accelerating entry portion, a stabilising midportion and a smoothly diffusing exit portion, a cascade of vanes arranged at the end of the entry portion to cause the accelerated entering fluid medium to whirl about the axis of the tube in a helical path and form a vortex in the stabilising portion where it stabilises itself, an annular opening at the end of the stabilising portion remote from the cascade of vanes for skimming off the outer and denser layer or layers of the whirling fluid medium together with any foreign matter contained therein and smoothly discharging it or them, and a cascade of vanes arranged downstream of the annular opening to straighten the flow of the remaining and cleaned fluid medium for smooth discharge from the diffusing exit portion substantially without breakaway of the flow from the end of the core member and substantially without turbulence.

The annular opening of the separator for the skimming off of the outer layer or layers of whirling fluid medium and the foreign matter contained therein may be defined by the fluid exit of the stabilising portion and the fluid inlet of the diffuser exit portion, the latter being of smaller diameter and projecting within the former which is shaped to form a divergent passage progressively increasing in cross-sectional area from a point of normal cross-sectional area upstream of the annular opening to a point of maximum cross-sectional area downstream of the annular opening for the smooth discharge of the denser layer or layers of whirling fluid medium and the foreign matter contained therein while the substantially clean fluid medium nearer the axis of the separator passes into the fluid inlet of the diffuser exit portion, the leading edge of which is made substantially sharp. A chamber may be arranged around the diffuser exit portion of the separator adjacent the annular opening to receive the denser layer or layers of the fluid medium and the foreign matter contained therein for discharge to a further separator or to waste.

The separator may be made conveniently in a number of parts fitting together and a number of separators may be arranged to nest together in parallel as a battery of separators.

In a battery each separator may be or have parts of hexagonal form for compactly nesting together and the denser layer or layers of fluid medium and the foreign matter contained therein from each separator may pass through each annular opening to the interstices formed between the separators.

The interstices are linked together to form a

single chamber by an outer casing surrounding the battery.

The single chamber is provided with an exhaust duct for discharging the denser layer of the fluid medium and the foreign matter contained therein to waste or to a further separator or separators of any known and appropriate type for the removal of the foreign matter from the remaining fluid medium.

The separators may also be used for anti-icing purposes in air entry ducts for air consuming plant for example compressor gas turbine plant or they may be used for separating dust and dirt from flue gases.

When using the separators for anti-icing purposes it will be essential to warm them to prevent ice accretion in the entrance portion and at the portion where the whirling air containing the foreign matter is skimmed off and discharged.

When using the separators in a flue it may be necessary to cool them to prevent them being burnt up.

The separator or separators in battery form may be arranged in a surrounding casing which may be divided into three chambers, one chamber for receiving the supply of warming or cooling fluid and extending from the entry portion up to the foreign matter discharge portion, a second chamber extending from and including the foreign matter discharge portion and approximately two thirds of the diffuser portion, and a third chamber for the discharge of warming or cooling fluid extending over the remaining third of the diffuser portion and end supporting fins. The whirl producing vanes in the entry portion of the separator and the supporting fins at the diffuser exit may be made hollow for the passage of warming or cooling fluid from the first chamber through the core member which may be of hollow construction and out of the third chamber. The whirl producing vanes when of hollow construction may be few in number and may extend over a considerable length of the entry portion of the separators.

Two forms of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a section through a separator with a part section of its core member.

Figure 2 is an end view of a battery of separators.

Figure 3 is a section through a battery of separators arranged as an anti-icing device and having passage for flow of warming fluid.

Figure 4 is an end view of the battery shown in Figure 3.

A separator (see Figure 1) for separating foreign matter from air or gas consists of an open ended tubular member 1 and a streamlined core member 2 contained within the tubular member, the two defining and forming between them an annular passage 3 through which the air or gas is passed. The tubular member 1 and the core member 2 are shaped to form a smoothly accelerating entry portion 4, a stabilising portion 5 and a smoothly diffusing exit portion 6. The smoothly accelerating entry portion 4 is formed between the sharply converging inner wall 7 of the tubular member 1 and the streamlined bullet shaped nose portion 8 of the core member 2 and the two defining a short convergent annular passage of sharply decreasing cross sectional area. The stabilising portion is formed between long walls 9 and 10 of the tubular member and the core member respectively and the two define a long

annular passage which may be of substantially constant cross sectional area or may be of progressively varying cross section area. The diffusing or diffuser exit portion 6 is formed between the slowly diverging inner wall 11 of the tubular member 1 and the slowly converging wall 12 of the core member 2, the two defining a long diverging annular passage of slowly increasing cross sectional area. At the junction of the accelerating entry portion 4 and the stabilising portion 5 a cascade of vanes 13 is arranged to cause the accelerated dusty and dirty entry air or gas to whirl about the axis of the separator in a helical path and form a vortex in the stabilising portion 5 where it stabilises itself. The vanes 13 may extend over a considerable length of the entry portion 4 and may be few in number, say five or six. An annular opening 14 is formed between the junction of the stabilising portion and the diffusing exit portion 6 for skimming off the outer layer or layers of the whirling air or gas and the foreign matter contained therein. The annular opening 14 is formed by the air or gas exit 15 of the stabilising portion 5 and the air and gas inlet 16 of the diffusing exit portion 6; the latter being of smaller diameter and projecting within the former which is shaped to form a divergent passage progressively increasing in cross sectional area from a point of normal cross sectional area upstream of the annular opening 14 to a point of maximum cross section area downstream of the annular opening 14 for the smooth discharge of the layer or layers of whirling air or gas containing foreign matter while the substantially clean air or gas nearer the axis of the separator passes into the inlet 16 of the diffusing exit portion 6, the leading edge 17 of which is made substantially sharp.

A little downstream of the annular opening 14 a cascade of straightening vanes 18 is arranged to straighten up the whirling air or gas for discharge from the diffusing exit portion 6 substantially without break-away of the flow from the end 19 of the core member 2 and substantially without turbulence.

With a single separator a chamber 20 is formed round the diffuser exit portion 6 into which the air or gas containing the foreign matter is discharged from the annular opening 14 for discharge to atmosphere or to another separator or separators of known and appropriate type for the removal of the foreign matter from the air or gas.

A number of separators may be arranged to nest together in parallel as a battery of separators (see Figure 2).

In the battery, each separator is made or contacting parts are made of hexagonal form for compactly nesting together. A battery of seven separators makes a convenient unit (see Figure 2). The air or gas containing the foreign matter from the openings 14 of each separator discharges into the interstices 20 formed between the diffusing exit portions of the separators and the interstices are linked together to form a single chamber by an outer casing 21 surrounding the battery. The chamber is provided with an exhaust duct 22 for discharging the air or gas containing the foreign matter either to atmosphere or to a further separator or separators of known and appropriate type for the removal of the foreign matter from the remaining air or gas.

In operation the air or gas containing the foreign matter enters the separators and is acceler-

ated in the accelerating entry portion. The fast moving air or gas in passing through the cascade of vanes is caused to whirl about the axis of each separator in a helical path to form a vortex, not necessarily a "free vortex" in the stabilising portion of the separator where it stabilises itself. The particles of foreign matter are centrifuged to the outside layer of the air or gas and are skimmed off with the air or gas layer by the substantially sharp leading edge of the diffusing exit portion and discharged through the divergent passage formed between the exit of the stabilising portion and the inlet of the diffusing exit portion to a chamber for discharge to atmosphere or to a further separator of known and appropriate type. The substantially clean air or gas passes on into the diffusing exit portion where it is straightened by the straightening cascade of vanes downstream of the annular opening and then discharged from the diffusing exit portion substantially without break-away from the end of the core member and substantially without turbulence.

The proportion of the foreign matter removed, that is the efficiency of the cleaning process is an implicit function of the geometrical design of the separator and of the operating mass flow of the separator.

For example, a non-rotary centrifugal separator may be 43 inches long overall, the lengths of the various portions making up the whole separator, being 5 inches for the accelerating entry portion including the cascade of vanes one inch in length for whirling the air, 18 inches for the stabilising portion and 20 inches for the diffusing exit portion. The overlapping divergent discharge passage for the dusty air which is formed as a continuation of the stabilising portion may be 3.5 inches long, making the total length of the stabilising portion 21.5 inches. The maximum diameter of the entry and exits may be 6 inches and the inside diameter of the stabilising portion may be 5.25 inches. The inside diameter of the air entry of the diffusing exit portion which projects into the stabilising portion where it commences to diverge may be 5 inches, the two forming between each other an annular orifice of approximately one eighth of an inch in width.

The core member is made slightly longer than the tubular member, the tail projecting slightly beyond the diffusing exit portion. It is made in three portions, a nose portion approximately 4 inches long, a central portion approximately 35 inches long, and a tail portion, approximately 3 inches long. The maximum diameter may be 3.5 inches and this diameter is maintained over the portion that is arranged within the stabilising portion of the separator. The portion of the core member arranged within the diffusing exit portion, tapers towards the tail end **19** to a minimum diameter of approximately 1 inch. The core member **2** is supported centrally by the cascade of vanes at entry, the cascade of straightening vanes and by a number of fins **23** engaging its tail portion **19** and projecting from the diffuser exit portion **6**.

The above non-rotary centrifugal separator is designed to remove foreign particles of approximately 10μ with an axial velocity of approximately 240 ft. per second with a total head loss of 3 inches of water, the mass flow of clean air being 1.4 lbs. per second.

When a greater mass flow of clean air is required, a battery of small separators as described above is to be preferred to one large separator.

In Figures 3 and 4 a battery of separators is shown arranged as a cleaning and anti-icing device for air flowing into an air duct of an air consuming plant, such for example, as an aircraft compresser gas turbine plant.

Each separator of the battery shown in Figure 3 is somewhat similar to the separator shown in Figure 1 and similar parts are given the same reference numeral.

The battery shown in Figures 3 and 4 is arranged in a surrounding casing **21***a* which is divided into three chambers, one chamber **27** for receiving a supply of warming fluid extends from the entry portion **4** to the foreign matter discharge or air or gas exit **15** at baffle **24**, a second chamber **20***a* extending from and including the foreign matter discharge or air or gas exit **15** at baffle **24** and approximately two thirds of the diffuser portion exit **6** to a baffle **25** and a third chamber **28** for the discharge of the warming fluid formed between the baffle **25** and an end partition **29** at the diffuser exit portion. The core member **2** is made hollow and hollow whirl producing vanes **13***a* in the entry portion **4** are provided for the passage of warming fluid from the chamber **27** to the hollow core member **2** and hollow fins **23***a* are provided for the passage of warming fluid from the core member **2** to the chamber **28** for discharge elsewhere.

The hollow whirl producing vanes are few in number say five or six and extend over a considerable length of the entry portion **4** of the separator.

The warming fluid inlet to the chamber **27** and exit from the chamber **28** are not shown.

The chamber **20***a* for the air containing the foreign matter is provided with an outlet **26**. It may be necessary to provide a flow of warm fluid to mix with the air flowing from the chamber **20***a* to prevent icing up of the outlet **26**.

A battery of separators for use in a flue for removing dust and dirt would be similar in construction to that shown in Figures 3 and 4. A cooling fluid, say air or water, would be used to cool the separators, the fluid passing into chamber **27**, through hollow vanes **13***a*, through hollow ore **2**, through hollow fins **23***a* to chamber **28** to be discharged.

It will be appreciated from the foregoing that in its application for anti-icing purposes to air intakes the separator operates on the basis of removing moisture particles from the incoming air flow and in that way of eliminating the possibility of ice formation at points further downstream in the flow. The application of the invention for anti-icing purposes thus has particular merit in relation to intakes for aircraft power plant, and especially compressor-turbine plant employing an axial flow compressor, in which case the most difficult problem in icing conditions is that of avoiding ice formation on the compressor blading. In this latter connection also, the use of the separator has the merit that it involves negligible heating of the entering air, thus minimising loss of compressor efficiency from that cause, since the passage walls require only to be maintained just above freezing point. For the same reason the use of the invention involves only a small power loss in providing for heating the walls, which may be easily effected by bleeding off hot gases from an appropriate point in the turbine system, for example its exhaust. It is true that the device

results in a permanent loss due to increase drag in the intake, which might be a disadvantage in special cases; in general, however, the penalty thus incurred will compare favourably with that which would be incurred by raising the temperature of the entering air, and in most cases will be avoidable by the provision of an alternative unobstructed intake for use when anti-icing provision is not desired.

I claim:

1. A nonrotary centrifugal separator for operating on a fluid medium containing foreign matter therein comprising a tubular core member having a bullet shaped nose wall, a tubular midwall and a truncated conical tail wall defining together a streamlined body having a cavity, a pair of open ended tubular members arranged around said core member in axial alignment with each other and defining with the core member an annular passage for the fluid medium, one of said tubular members being an entry and stabilizing member having a convergent entry wall co-extensive with said bullet shaped nose wall and a tubular stabilizing wall co-extensive with said tubular midwall and a divergent tail wall and the other of said tubular members being a diffusing exit member having a divergent exit wall co-extensive with said conical tail wall and a tubular entry wall projecting within said divergent tail wall and defining therewith an annular outlet from said annular passage, a cascade ring of radially arranged whirl producing vanes extending across said annular passage adjacent the junction of said bullet shaped nose wall and said tubular midwall and the junction of said convergent entry wall and said tubular stabilizing wall to space said core member and said one tubular member apart and to impart a whirl to said fluid medium on its way through said annular passage to centrifuge said foreign matter from the inner layers to the outer layers of said fluid medium to be skimmed off by said tubular entry wall for discharge through said annular opening and allow the cleaned inner layers to pass axially to said diffusing exit member, a cascade ring of radially arranged straightening vanes extending across said annular passage from said core member to the said tubular entry wall adjacent said annular opening to space them apart and straighten the flow of said cleaned fluid medium, and a ring of radially arranged fins extending across said annular passage from said conical tail wall to said diffusing exit member to space said core member from said diffusing exit member.

2. A nonrotary centrifugal separator for operating on a fluid medium containing foreign matter therein comprising a tubular core member having a bullet shaped nose wall, a tubular midwall and a truncated conical tail wall defining together a streamlined body having a cavity, a pair of open ended tubular members arranged around said core member in axial alignment with each other and defining with the core member an annular passage for the fluid medium, one of said tubular members being an entry and stabilizing member having a convergent entry wall co-extensive with said bullet shaped nose wall and a tubular stabilizing wall co-extensive with said tubular midwall and a divergent tail wall and the other of said tubular members being a diffusing exit member having a divergent exit wall co-extensive with said conical tail wall and a tubular entry wall projecting within said divergent tail wall and defining therewith an annular

outlet from said annular passage, a cascade ring of radially arranged whirl producing vanes extending across said annular passage adjacent the junction of said bullet shaped nose wall and said tubular midwall and the junction of said convergent entry wall and said tubular stabilizing wall to space said core member and said one tubular member apart and to impart a whirl to said fluid medium on its way through said annular passage to centrifuge said foreign matter from the inner layers to the outer layers of said fluid medium to be skimmed off by said tubular entry wall for discharge through said annular opening and allow the cleaned inner layers to pass axially to said diffusing exit member, a cascade ring of radially arranged straightening vanes extending across said annular passage from said core member to the said tubular entry wall adjacent said annular opening to space them apart and straighten the flow of said cleaned fluid medium, a ring or radially arranged fins extending across said annular passage from said conical tail wall to said diffusing exit member to space said core member from said diffusing exit member, a passage extending through at least one of said whirl producing vanes to provide an inlet to said cavity in said core member for the passage of heat exchange fluid thereto, and a passage extending through at least one of said fins to provide an exit from said cavity in said core member for the passage of heat exchange fluid therefrom.

3. A nonrotary centrifugal separator for operating on a fluid medium containing foreign matter therein comprising a tubular core member having a bullet shaped nose wall, a tubular midwall and a truncated conical tail wall defining together a streamlined body having a cavity, a pair of open ended tubular members arranged around said core member in axial alignment with each other and defining with the core member an annular passage for the fluid medium, one of said tubular members being an entry and stabilizing member having a convergent entry wall co-extensive with said bullet shaped nose wall and a tubular stabilizing wall co-extensive with said tubular midwall and a divergent tail wall and the other of said tubular members being a diffusing exit member having a divergent exit wall co-extensive with said conical tail wall and a tubular entry wall projecting within said divergent tail wall and defining therewith an annular outlet from said annular passage, a cascade ring of radially arranged whirl producing vanes extending across said annular passage adjacent the junction of said bullet shaped nose wall and said tubular midwall and the junction of said convergent entry wall and said tubular stabilizing wall to space said core member and said one tubular member apart and to impart a whirl to said fluid medium on its way through said annular passage to centrifuge said foreign matter from the inner layers to the outer layers of said fluid medium to be skimmed off by said tubular entry wall for discharge through said annular opening and allow the cleaned inner layers to pass axially to said diffusing exit member, a cascade ring of radially arranged straightening vanes extending across said annular passage from said core member to the said tubular entry wall adjacent said annular opening to space them apart and straighten the flow of said cleaned fluid medium, a ring or radially arranged fins extending across said annular passage from said conical tail wall to said diffusing exist member to space said core member from said diffusing exit

member, a passage extending through at least one of said whirl producing vanes to provide an inlet to said cavity in said core member for the passage of heat exchange fluid thereto, and a casing wall enclosing said pair of tubular members having an internal wall extending from said divergent tail wall of said entry and stabilizing member to said casing wall and a second internal wall extending from said exit diffusing member to said casing wall and defining three separate chambers, a central one associated with said annular outlet passage and having an outlet duct for the discharge of fluid medium containing foreign matter, an end one associated with said inlet passage through said whirl producing vanes and having a fluid inlet duct for the passage of heat exchange fluid thereto, and another end one associated with said outlet passage through said fin and having a fluid outlet duct for the passage of heat exchange fluid therefrom.

4. A nonrotary centrifugal separator for operating on a fluid medium containing foreign matter therein comprising a streamlined core member having a bullet shaped nose member, a truncated conical tail member and a tubular wall member extending between said nose member and said tail member having over half the length of said core member a cylindrical shape conforming to the maximum diameter of said nose member and over the remainder of the length of the core member a conoidal shape conforming at one end to a diameter equal to the diameter of said nose member and at the other end to the maximum diameter of said conical tail member, a pair of open ended tubular members arranged around said core member in axial alignment with each other and defining with the core member an annular passage for the fluid medium, one of said tubular members being an entry and stabilizing member having a convergent entry wall co-extensive with said bullet shaped nose member and a tubular stabilizing wall co-extensive with said core wall of cylindrical shape and a divergent tail wall and the other of said tubular members being a diffusing exit member having a divergent exit wall co-extensive with said conoidal shaped length of said core member and said conical tail member and a tubular entry wall projecting within said divergent tail wall and defining therewith an annular outlet from said annular passage, a cascade ring of radially arranged whirl producing vanes extending across said annular passage adjacent the junction of said bullet shaped nose member and said tubular wall member and the junction of said convergent entry wall and said tubular stabilizing wall of said one tubular member to space said core member and said one tubular member apart and to impart a whirl to said fluid medium on its way through said annular passage to centrifuge said foreign matter from the inner layers to the outer layers of said fluid medium to be skimmed off by said tubular entry wall for discharge through said annular opening and allow the cleaned inner layers to pass axially to said diffusing exit member, a cascade ring of radially arranged straightening vanes extending across said annular passage from said core member to said tubular entry wall adjacent said annular opening to space them apart and straighten the flow of said cleaned fluid medium and a ring of radially arranged fins extending across said annular passage from said conical tail member to said diffusing exit tail member to space said core member from said diffusing exit tail member.

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